EVOLUTION OF WIRELESS COMMUNICATIONS TOWARDS 5G AND BEYOND (2020-2030)

DR. LWAA FAISAL AL-TIMIMY

lwaa@kecbu.uobaghdad.edu.iq

2023


بسم الله الرحمن الرحيم


وقل رب زدني علما

OUTLINE

- HISTORY OF CELLULAR TELEPHONY
- ✓IMT-1990 (2G)
- ✓IMT-2000 (3G)
- ✓IMT-Advanced (4G)
- ✓IMT-2020 (5G)
- Requirements of 5G
- Growth in IMT traffic
- 5G scenarios
- 5G usage scenarios for 2020 and beyond

Introduction

- Mobile communications is now intricately tied to socio-economic fabric of the modern generation human beings
- The tight coupling between mobile communication systems and socio-technical trends are expected to continue beyond 2020
- Also it is foreseen that, there will be

❖ More traffic volume

❖ More devices with diverse service requirements

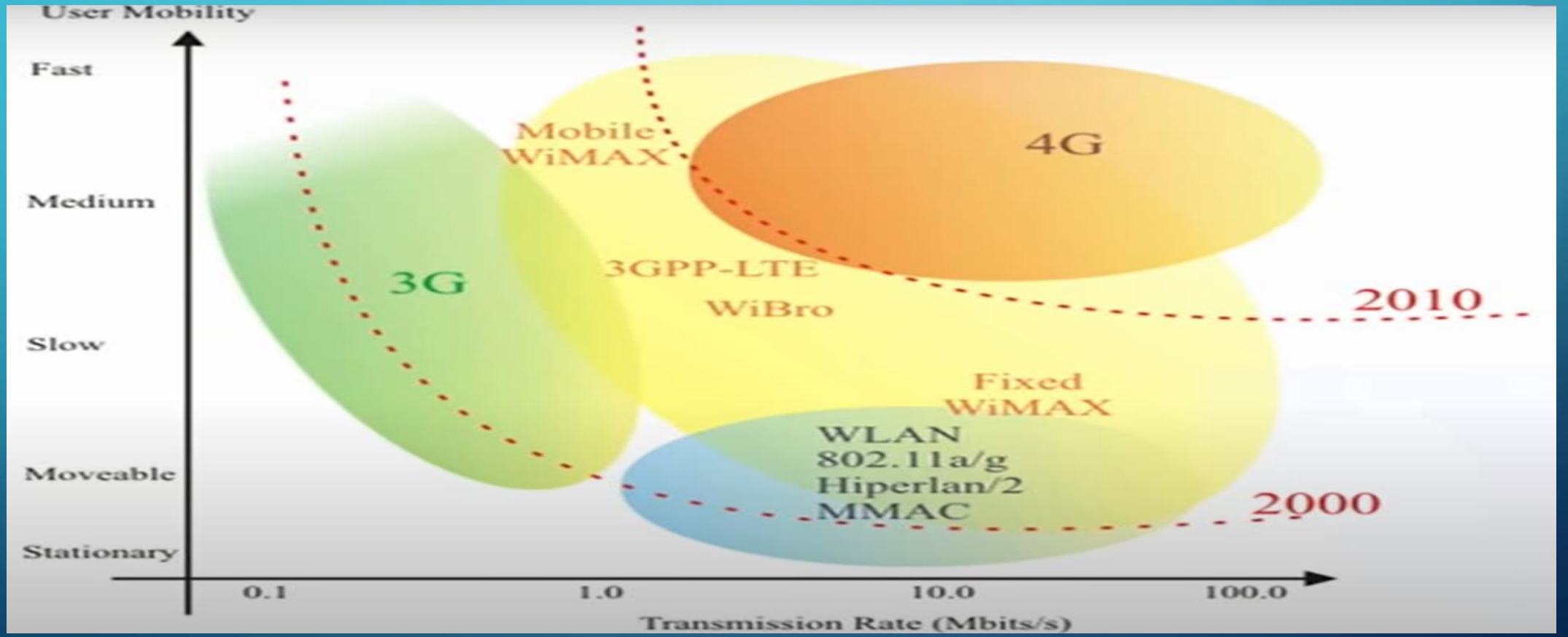
❖ Better quality of user experience (QoE)

❖ will require an increasing number of innovative solutions

HISTORY OF CELLULAR TELEPHONY

1G	2G	2.5G	3G	Beyond 3G	4G
Analog voice	Digital voice	Voice + data	Multimedia services	Broadband multimedia	Ubiquitous networks
NMT AMPS	GSM PDC IS-95A IS-136	GPRS HSCSD EDGE IS-95B	WCDMA CDMA 2000	HSPA WiMAX UMTS-LTE CDMA 2000 1xEV	IMT-A
FM modulation Analog switching Cellular concept Hard handover	Digital modulation Error control Data compression Soft handover High quality voice	Voice + data Higher rate than 2G	'Any time any where' multimedia Packet based data Dynamic RRM Increased capacity	Broadband multimedia High data rate High QoS support broadband wide area	Heterogeneous networks Adaptive air interface Guaranteed QoS Real broadband at wide-area
FDMA	TDMA/CDMA	TDMA/CDMA	WCDMA	WCDMA/OFDMA	OFDMA
very low rate	9.6-28.8kbps	57-115kbps	0.144~2Mbps	~10's of Mbps	~100's of Mbps
1970s/1980s	**1982/1992**		**1992/2001**	**..../2007**	**2010**

RECENT PAST WIRELESS COMMUNICATION SYSTEMS



EVOLUTION OF WIRELESS COMMUNICATION STANDARDS FROM 2G TO 5G

- **2G: GSM (Global System for Mobile Communication)**

✓ The European Conference of Post and Telecommunication Administration (CEPT).

✓ Group Special Mobile

○ To provide digital mobile communications across Europe with objectives

❑ Better and efficient wireless communication than analog.

❑ Single standard for all Europe.

✓ After several proposals

❑ TDMA was agreed upon by several organizations because of common agreement.

- **IMT-2000 (3G) (Objectives To):**

✓Make voice and non-voice telecommunication services available to users who are

❑Mobile

❑Roaming

✓Accommodate variety of mobile terminals

❑Small: carried on person

❑are mounted in vehicles

- **Technologies introduced in 3G++**
- Variable Data Rates
  - Multiple code word assignment (variable spreading factor)
  - Modulation (QPSK, 16 QAM)
  - Code Rate (not only ½ but also different code rates)
- Coverage/ Improvement
  - Turbo code
  - Hybrid ARQ
  - Link Adaption
- Capacity Improvement
  - Multiantenna Transmission

- **IMT-Advanced (support) (ITU-R-M 2134)**

➢ Low to high mobility applications

➢ Wide range of data rates

- Peak data rats: 100 Mbps for high mobility and 1 Gbps for low mobility

➢ High quality multimedia applications

➢ Worldwide roaming

- **Minimum Requirements for IMT-Advanced**

➢ **Cell Spectral Efficiency**

❑ Let x_i denote the number of correctly received bits by user i (downlink) in a system comprising of

- N users
- M cells
- W channel bandwidth
- T time over which the data bits are received

❖ The cell spectral efficiency is given by

$$\xi = \sum_{i=1}^{N} \frac{x_i}{T.W.M}$$

- **Cell Spectral Efficiency (Cont.)**

Test environment	Downlink (bit/s/Hz/cell)	Uplink (bit/s/Hz/cell)
Indoor	3	2.25
Microcell	2.6	1.80
Base coverage urban	2.2	1.4
High speed	1.1	0.7

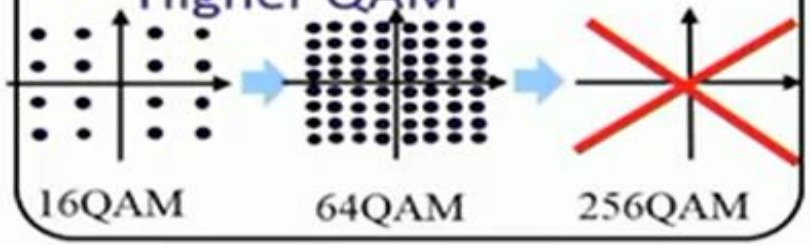
These values were defined assuming antenna configuration of downlink 4×2 and uplink 2×4

- **Peak Spectral Efficiency**
- Peak spectral efficiency is defined as the highest theoretical data rate normalized by B.W., which is the received data bits assuming error free conditions assignable to a single MS.
- **Minimum requirements for peak spectral efficiency:**
- Downlink peak spectral efficiency is 15 bit/s/Hz
- Uplink peak spectral efficiency is 6.75 bit/s/Hz

These values were defined assuming antenna configuration of downlink 4×4 and uplink 2×4

Main Components OF 4G Systems

- Higher QAM



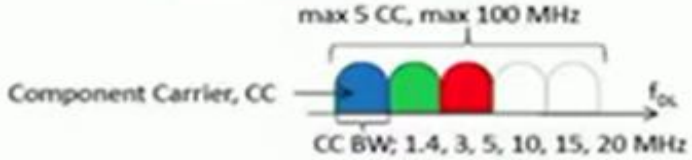
- MAC optimization

Packet Switching

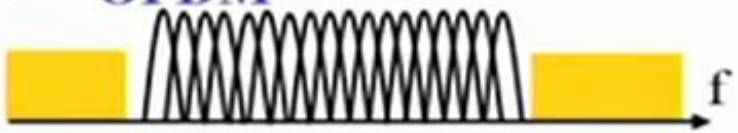
Packet Scheduling

Radio Resource Allocation.

Carrier Aggregation



- OFDM



Increasing the number of sub-carriers; 1.25times (IEEE 802.11)

Turbo Encoder & Decoder

HARQ

Link Adaptation

- MIMO

Channel capacity becomes N times for SISO

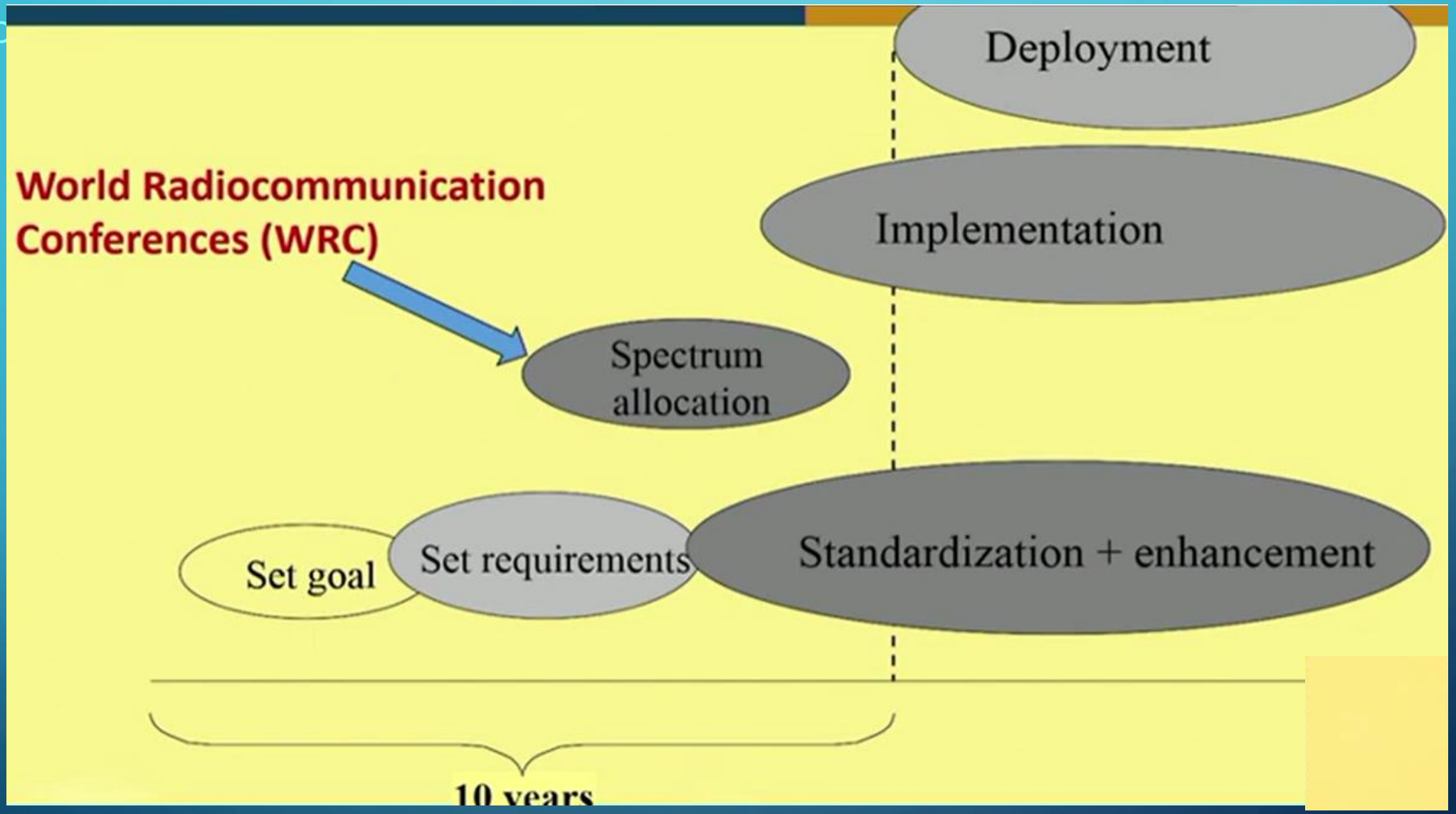
IMT-2020 (5G)

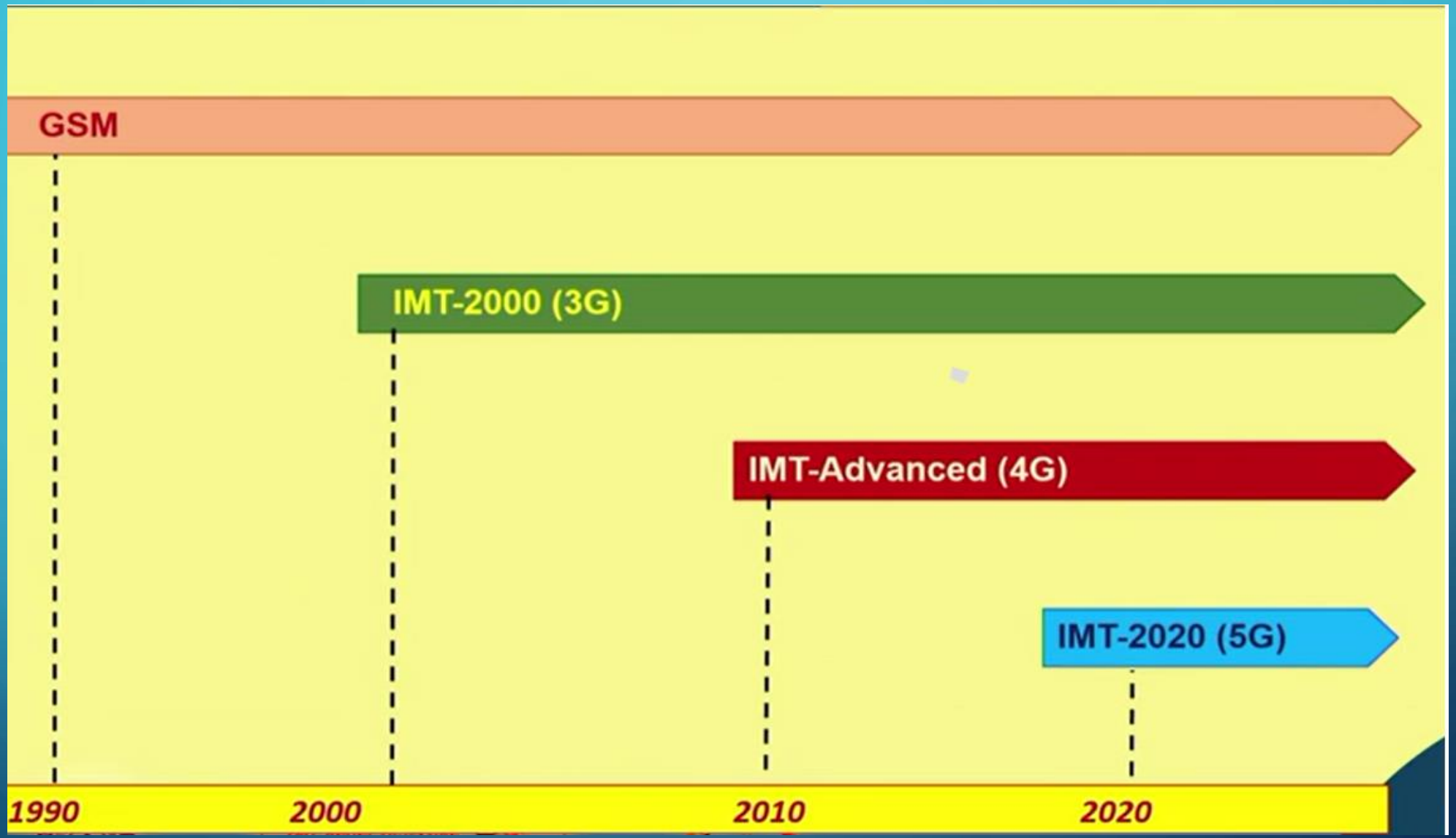
- **Concepts Covered**

✓ **Requirements of IMT-2020**

✓ **Traffic Prediction**

✓ **Operating Scenarios**


Deployment
World Radiocommunication Conferences (WRC)
Implementation
Spectrum allocation
Set goal
Set requirements
Standardization + enhancement
10 years


GSM
IMT-2000 (3G)
IMT-Advanced (4G)
IMT-2020 (5G)
1990
2000
2010
2020

Requirements of 5G/IMT-2020

- High level network architecture
- End-to-end QoS framework
- Emerging network technologies, and
- Network softurazation

Requirements of IMT-2020

- IMT-2020 [b-ITU-RM-2083-0] system that support to provide far more enhanced capabilities than those described in Recommendation ITU-R-M.1645]
- There is a reference ITU-R Recommendation ITU-RM-2083-0 “IMT vision-framework and overall objectivities of the future deployment of [IMT for 2020 and beyond]
- The term IMT-2020 is commonly referred to “fifth generation mobile networking” or simply 5G
- IMT-2020 and 5G are synchronous

Observations

- Wireless communication applications are expected to facilitate
  - ❑ The digital economy, ex. Smart grid, e-health, intelligent transport systems and traffic control
    - ➢ Which would bring requirements beyond what can be addressed in ITM application areas
- Rapid adoption of smart phones and mobile applications
  - ➢ Cause a tremendous increase in the volume of mobile data traffic
- Number of devices accessing the network are expected to increase due to
  - ○ Proliferation of Internet of Things (IoT)

Technologies Such as

- Beamforming and massive MIMO
- are aligned with higher frequencies
- Wide contiguous bandwidth would
- Enhance data delivering efficiency and case of hardware implementation
- Reduced cell size (the order of some tens of meters)
- Provide larger area-traffic capacity in dense area

User and Application Trends

- **Future IMT systems should support emerging new user cases, including applications requiring**

➢ Very high data rate communications,

➢ A large number of connected devices

➢ Ultra-low latency

➢ High reliability applications

Very Low Latency and High Reliability Human-Centric Communication

- Flash behavior is

❑A key factor for the success of:

➢ cloud services

➢Virtual reality and

❑Low latency and high reliability communications are enabler for

➢E-health

➢Safety

➢Office

➢Entertainment and other sectors

Very Low Latency and High Reliability Human-Centric Communication

- **Day communication systems are**

❖designed with the human in mind

- Design is to consider Machine-to-Machine (M2M) communication with real time constraints

❑**Examples of where low latency and high reliability can improve quality of life.**

- Driverless cars, enhanced mobile cloud services, real time traffic control optimization, emergency and disaster response, smart grid, e-health, efficient industrial communications
- UAVs

Higher User Density

- Requirement: satisfactory end-user experience in the presence of a large number of concurrent users, example
- Crowd with a high traffic density per unit area and a large number of handsets and machines/devices per unit area
- Audio-visual content to be provided concurrently or infotainment applications in
  - Shopping malls
  - Stadiums, open air festivals
  - Other public events that attract a lot of people

Higher User Density

- This includes users who use phones
  - While in unexpected traffic jams,
  - While in public transportation system,
  - In organizations such as police, fire brigades
  - UAVs

High Quality and High Mobility

- **Maintaining high quality and high mobility**
  - Helps successful deployment of application or user equipment located inside cars or high speed trains
- **Enhanced multimedia services are driven by**
  - Increasing demand for mobile high-definition multimedia in
    - Entertainment, medical treatment, safety and security areas
- Further, users will get devices with
  - Ultra-high Definition display, multi-view High Definition display,
  - Mobile 3D projections, immersive video conferencing display

- **Mobility**
- **Definition of mobility cases**

➢ **Stationary: 0 Km/h**

➢ **Pedestrian: > 0 Km/h to 10 Km/h**

➢ **Vehicular: 10 to 120 Km/h**

➢ **High speed: 120 to 350 Km/h**

➢ **Very high speed: 350 to 500 Km/h**

Internet of Things: Drivers for Different Requirements

- # of connected things will exceed # of human user devices
- Connected :things" can be

✓ Smartphones, sensors, actuators, cameras, vehicles, etc,

- Theses connected devices Varying levels of

➢ Energy consumption

➢ Transmission power

➢ Latency requirements

➢ Cost, and other indices for suitable operation

Internet of Things: Drivers for Different Requirements

- Application areas
  - Agriculture
  - Health care
  - Vehicle-to-vehicle and vehicle -to -road infrastructure communication

Ultra-Accurate Positioning Applications

- Precise ground based navigation service
- Unmanned vehicles
- Drones may expected extensively
- Relief operations
- Anti-subversive operations
- Rescue missions
- Etc.

Growth in IMT Traffic

- Many drivers influence the growth of traffic demands, which in turn influence the technical requirements

➢ Adaption of devices with enhanced capabilities

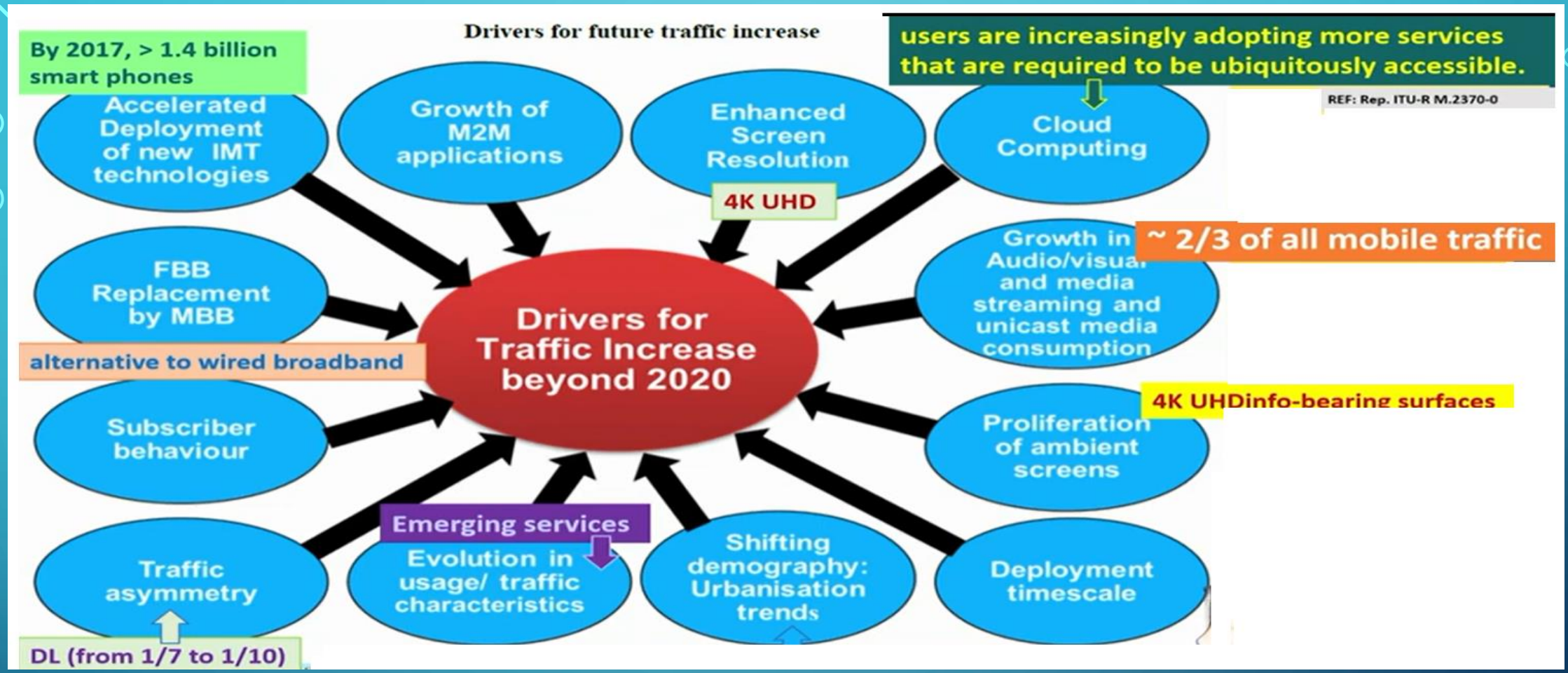
➢ Increased video usage

➢ Device proliferation

➢ New applications (evolving with time)

➢ ITU –R2370: Drivers and other trends which impact traffic growth

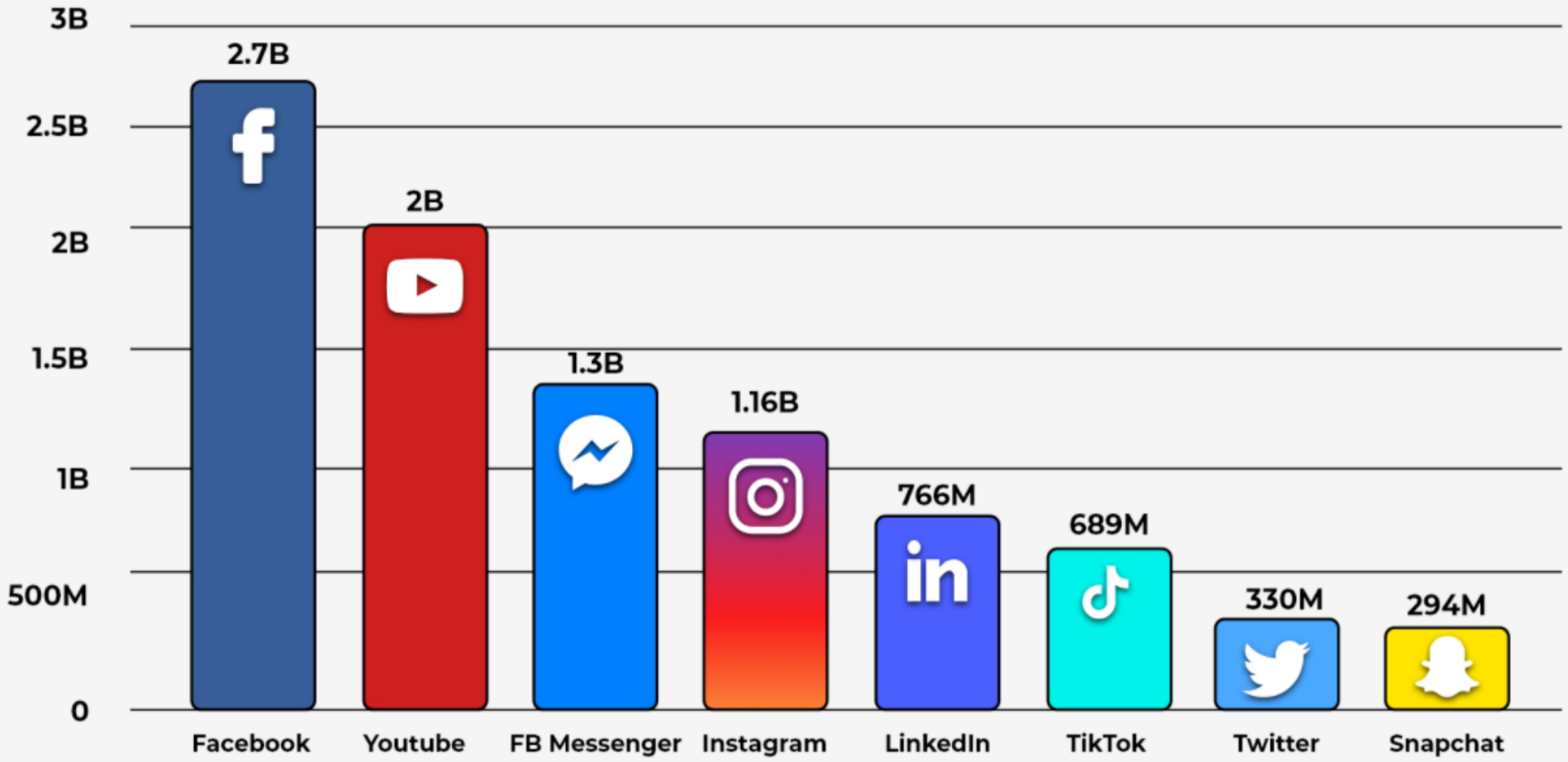
(Application global IMT traffic will grow 10-100X from 2020 to 2030)



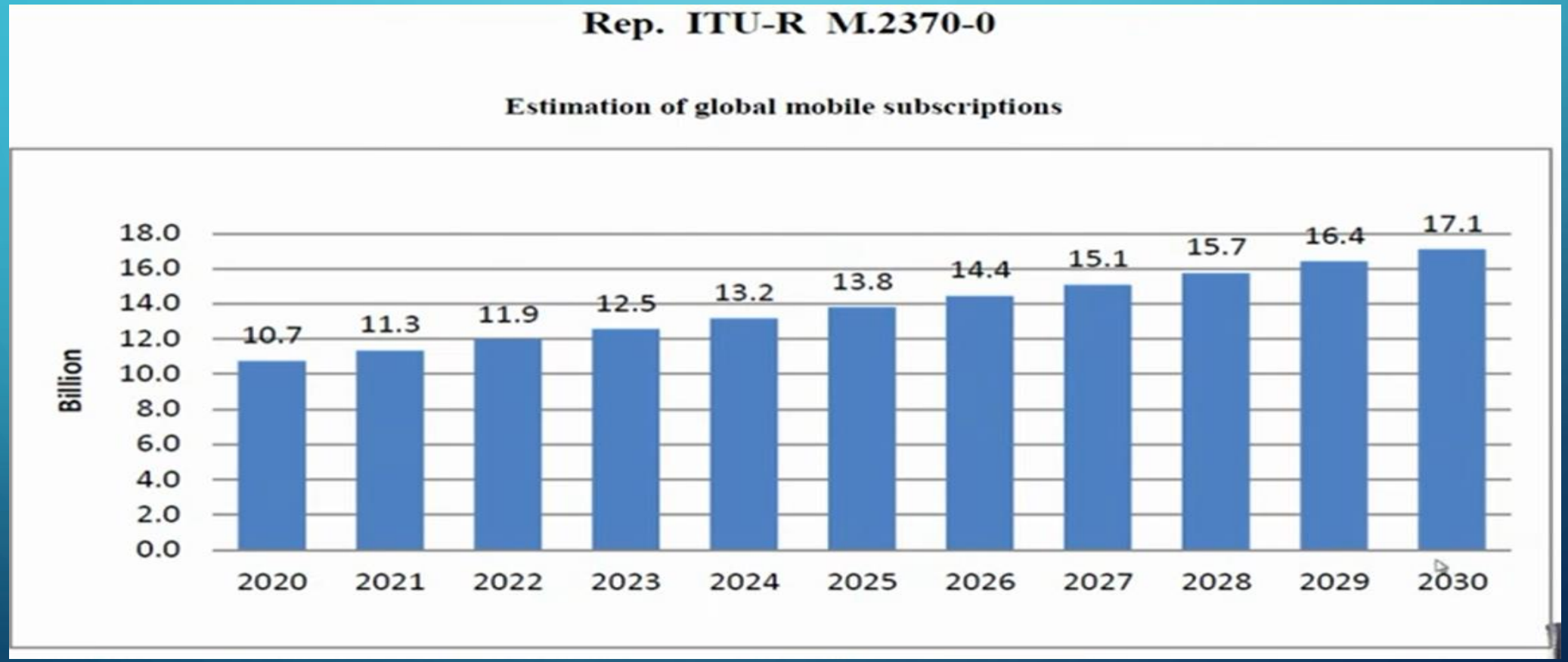
- ANNUAL GLOBAL DOWNLODING OF APPLICATIONS ~325 BILLION IN 2020
- MOST APPLICATIONS ARE NOT USED MORE THAN ONCE AFTER DOWNLOADING
- ADDITIONALIY, THE AMOUNT OF REGULAR UPDATES/UPGRADES

- There were 4.66 billion active internet users around the world in January 2021. That's close to 60% of the world population. (2.6 billion internet users in 2013).
- There were 319 million new internet users in 2020.
- Expect to use between 0.5MB and 1.3MB per minute for a VoIP call.
- In 2024, the number of emails will be about 361 billion every day.
- Cloud data storage around the world will amount to 200+ Zettabytes by 2025.
- Machine-generated data accounted for over 40% of internet data in 2020.
- By 2023, there are expected to be around 1.3 billion IoT subscriptions.
- The number of IoT devices will reach 25.44 billion in 2030. (In 2019, the number of connected devices was only 7.74 billion).

Most Popular Social Platforms
Total Active Users

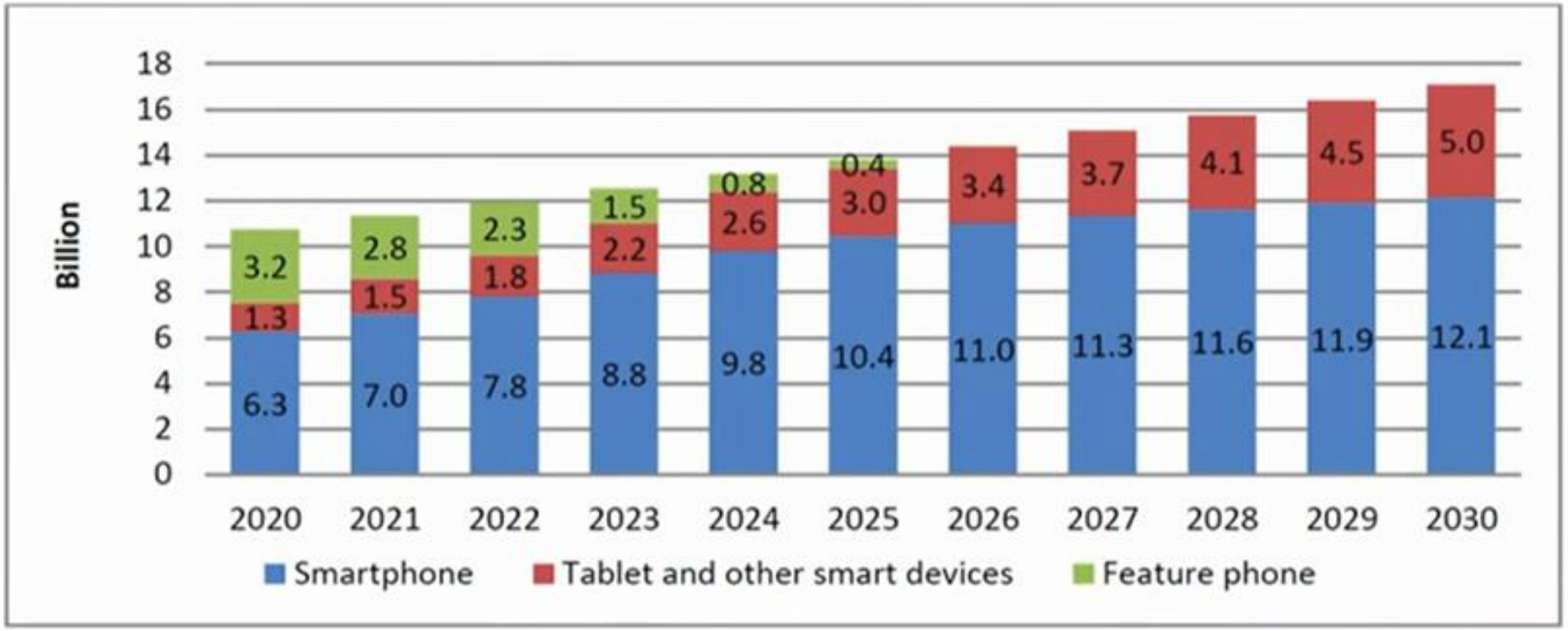


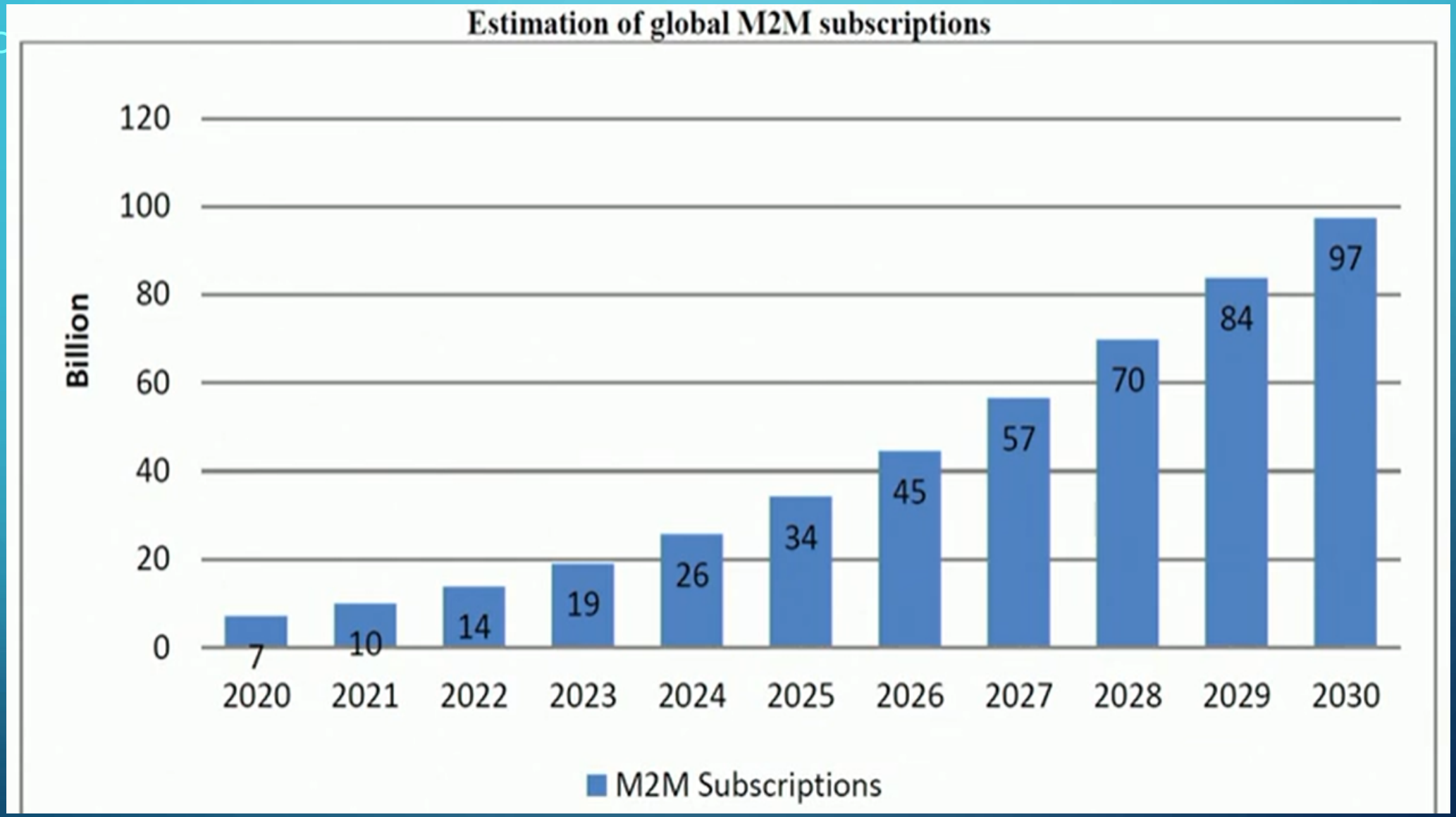
Global Mobile Subsicriptions-6.7 Billion in 2003

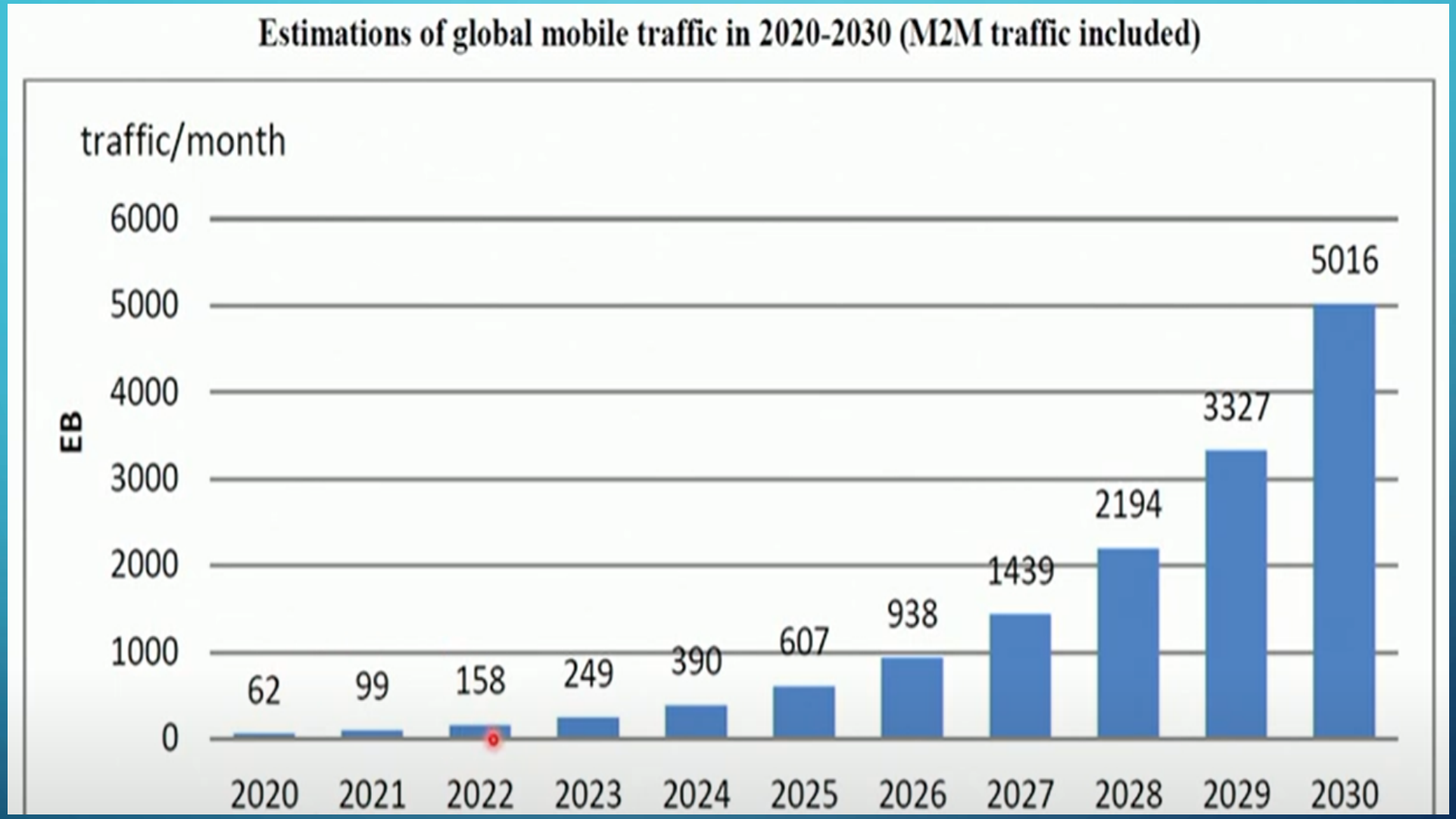


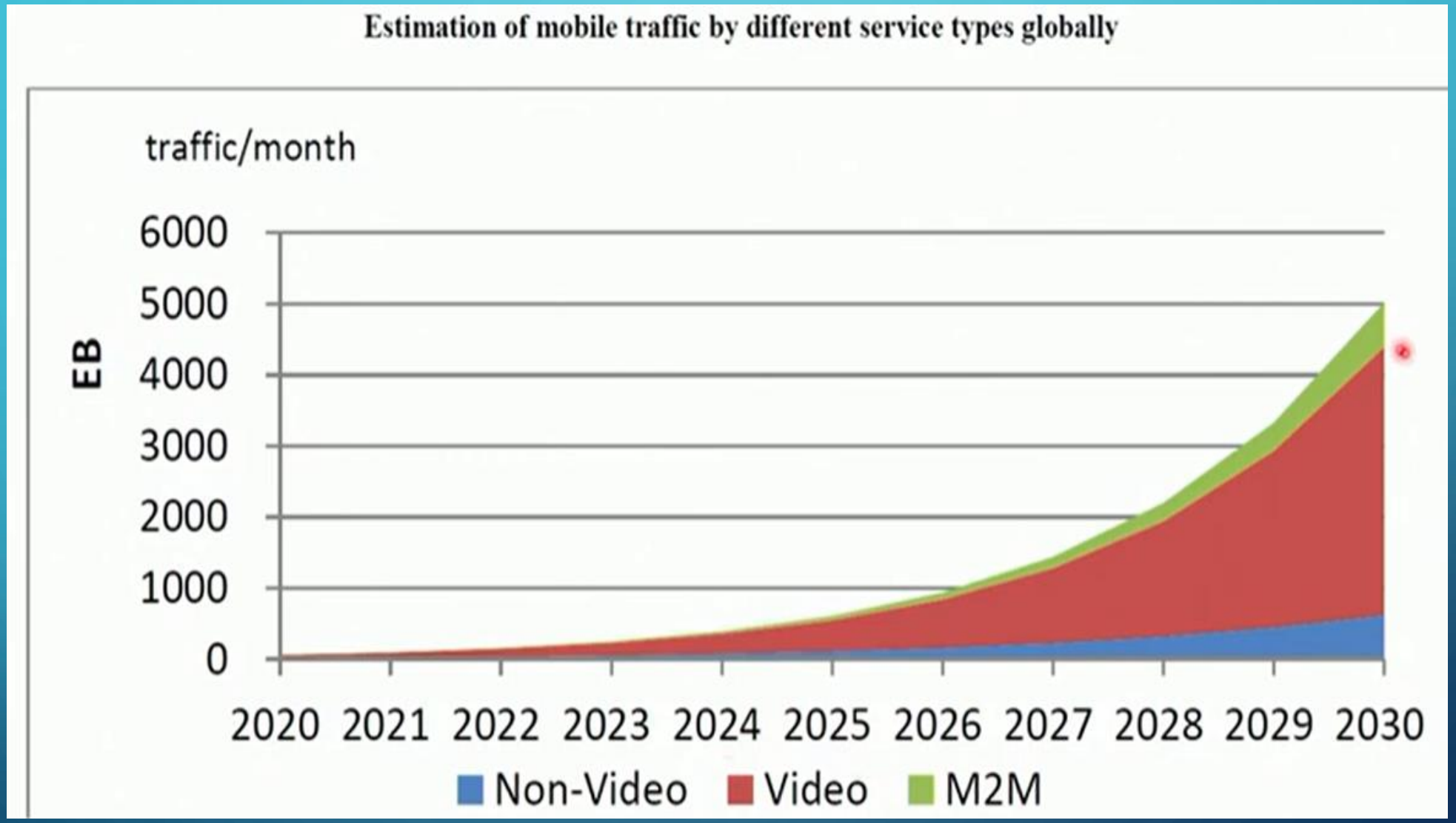
Rep. ITU-R M.2370-0

Estimation of global mobile subscriptions with different categories



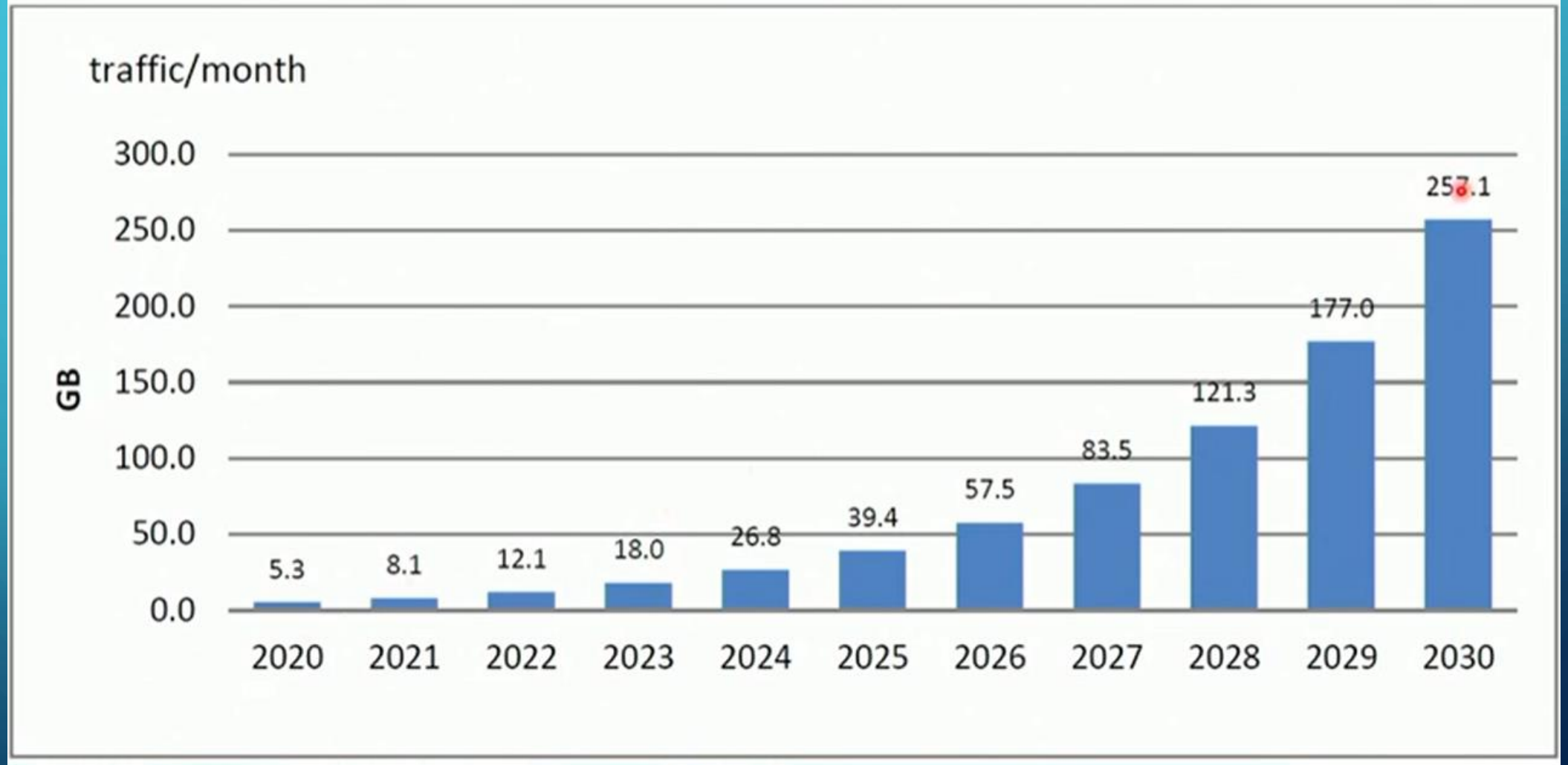

Estimation of global M2M subscriptions
Billion
120
100
80
60
40
20
0
7
10
14
19
26
34
45
57
70
84
97
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
M2M Subscriptions

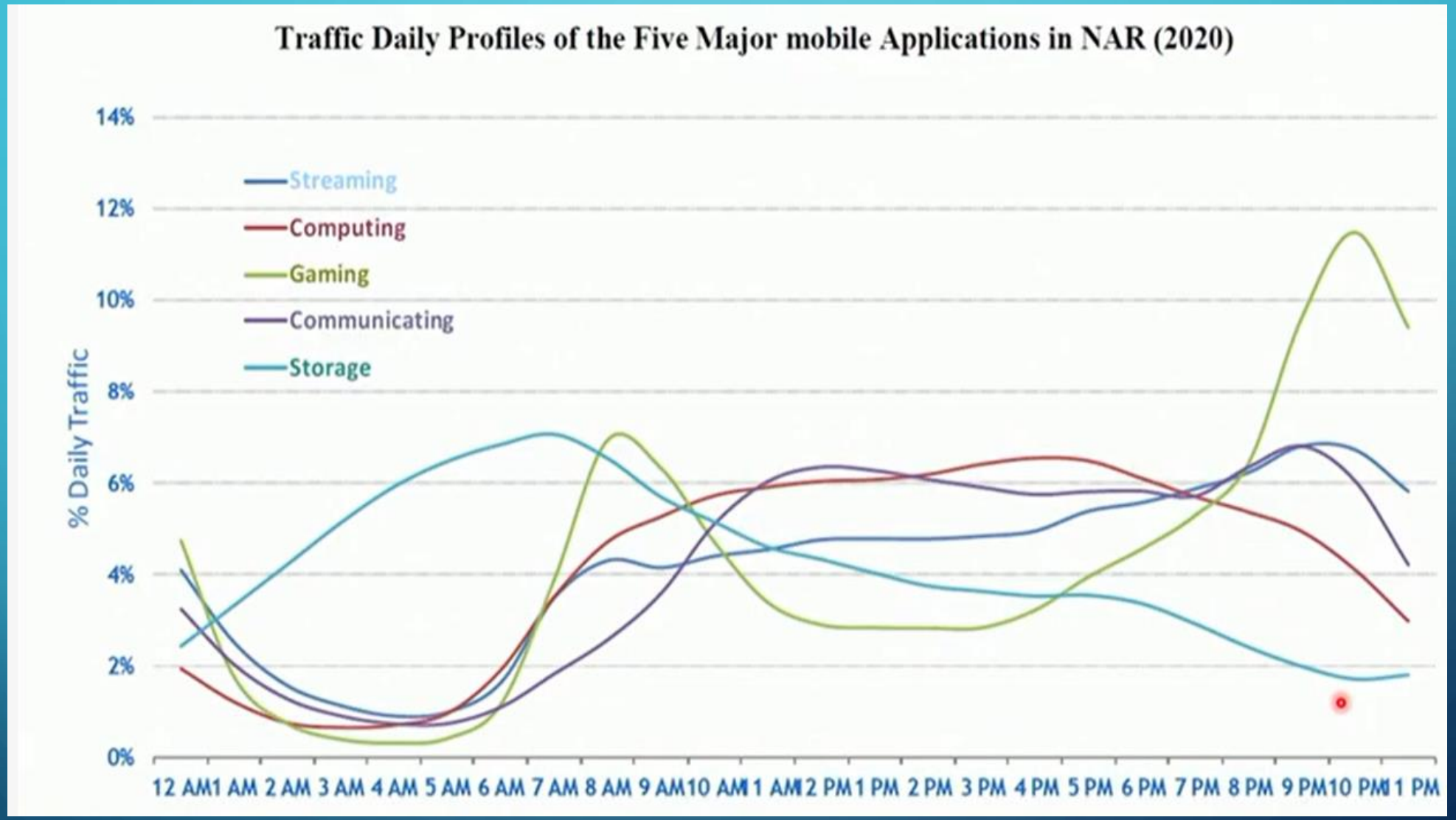

Estimations of global mobile traffic in 2020-2030 (M2M traffic included)
traffic/month
EB
6000
5000
4000
3000
2000
1000
0
62
99
158
249
390
607
938
1439
2194
3327
5016
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030


Estimation of mobile traffic by different service types globally
traffic/month
EB
6000
5000
4000
3000
2000
1000
0
2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Non-Video
Video
M2M

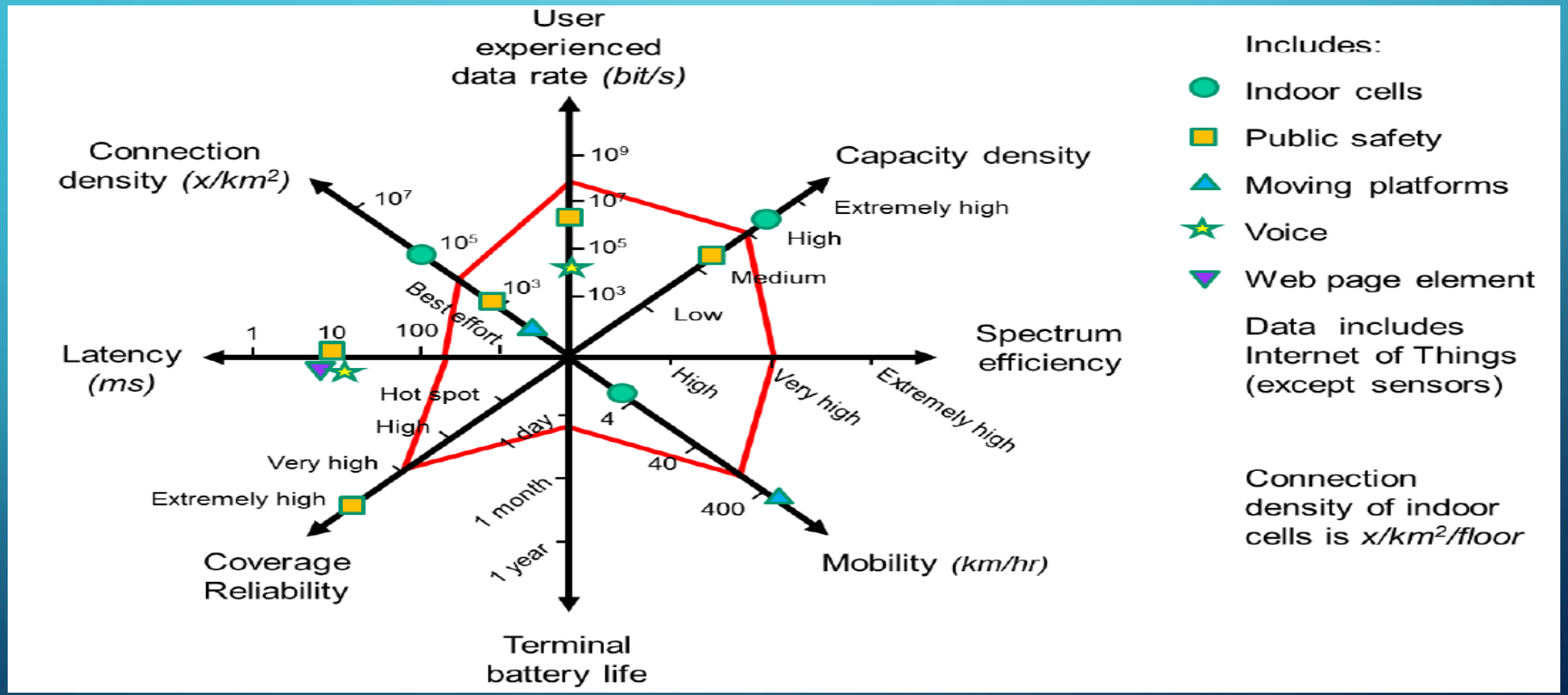
Estimations of global mobile traffic per subscriptions per month from 2020 to 2030

(M2M not included)

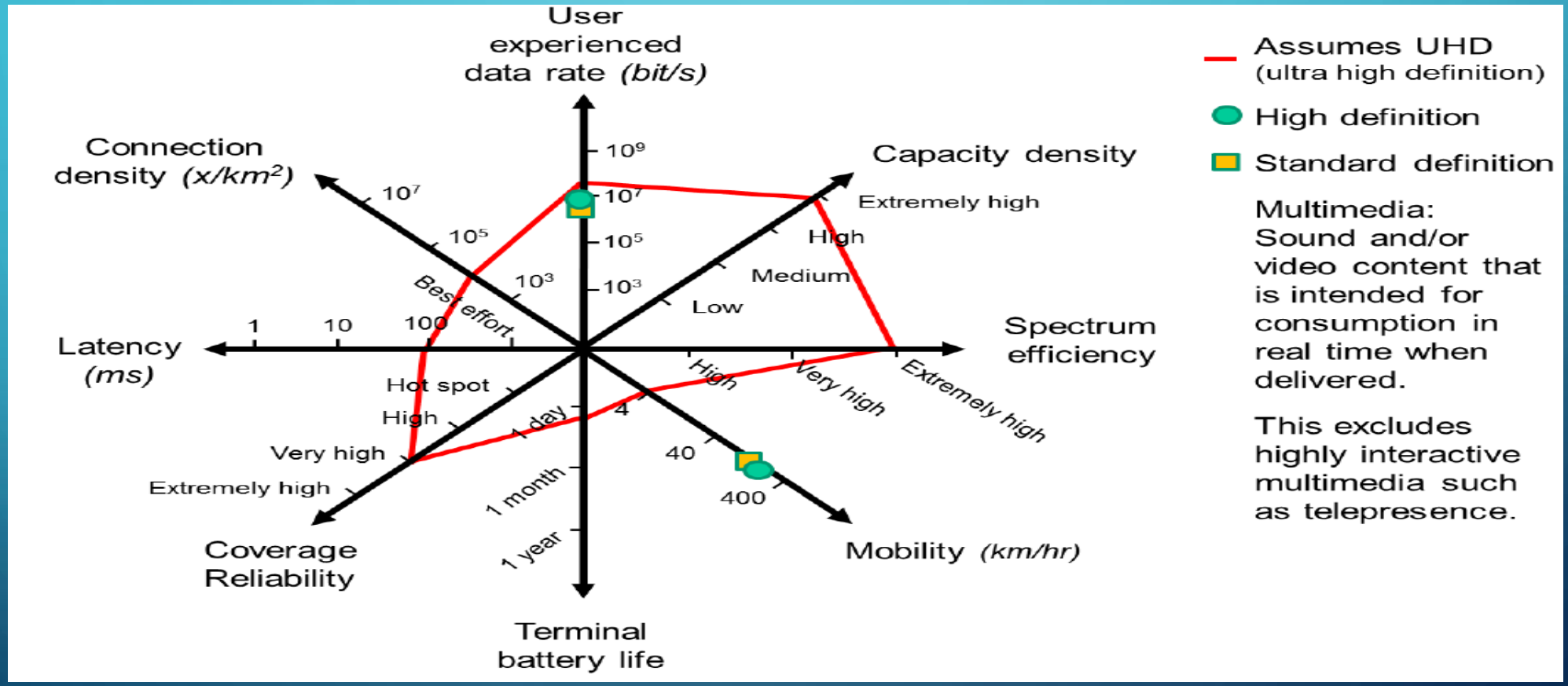



Traffic Daily Profiles of the Five Major mobile Applications in NAR (2020)
14%
12%
10%
8%
6%
4%
2%
0%
% Daily Traffic
Streaming
Computing
Gaming
Communicating
Storage
12 AM 1 AM 2 AM 3 AM 4 AM 5 AM 6 AM 7 AM 8 AM 9 AM 10 AM 1 AM 2 PM 1 PM 2 PM 3 PM 4 PM 5 PM 6 PM 7 PM 8 PM 9 PM 10 PM 1 PM

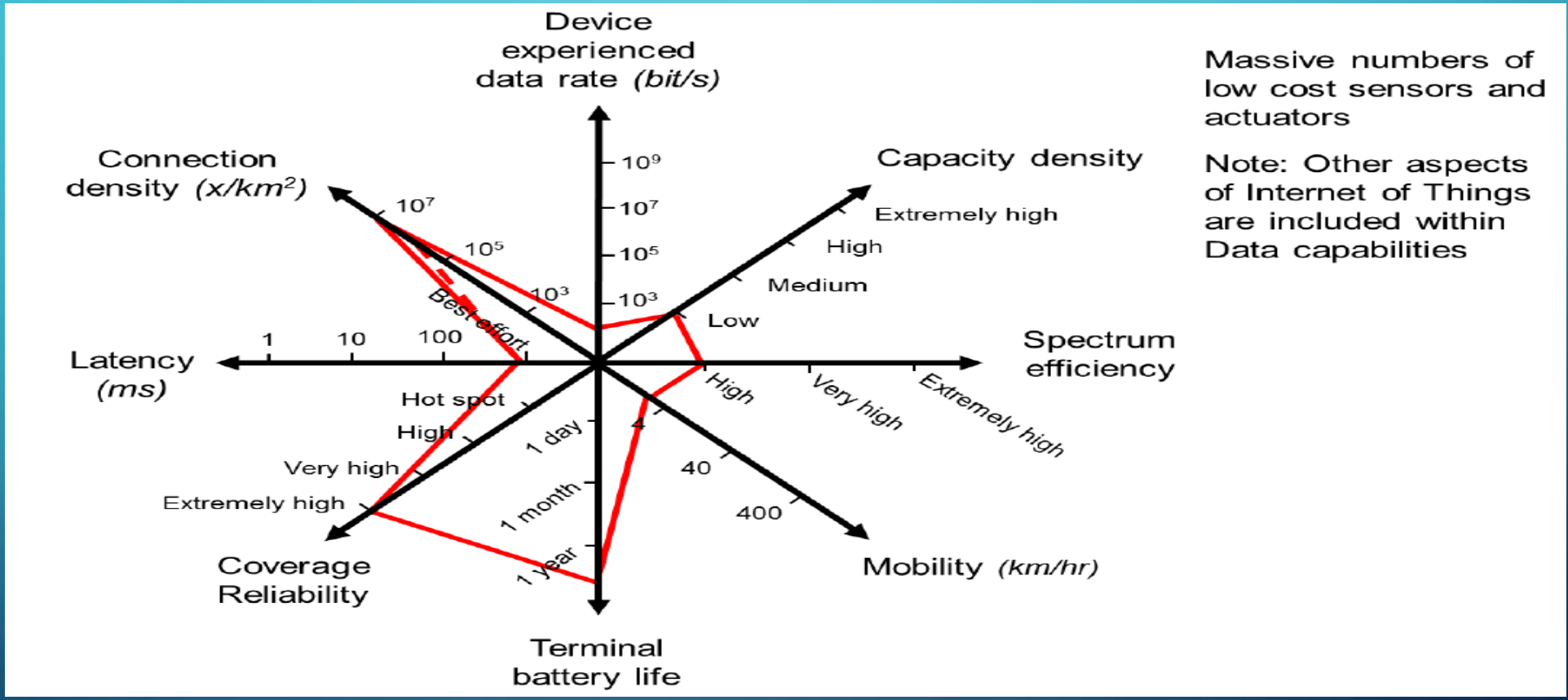
Capabilities Envisaged for Current and Emerging Voice and Data Applications



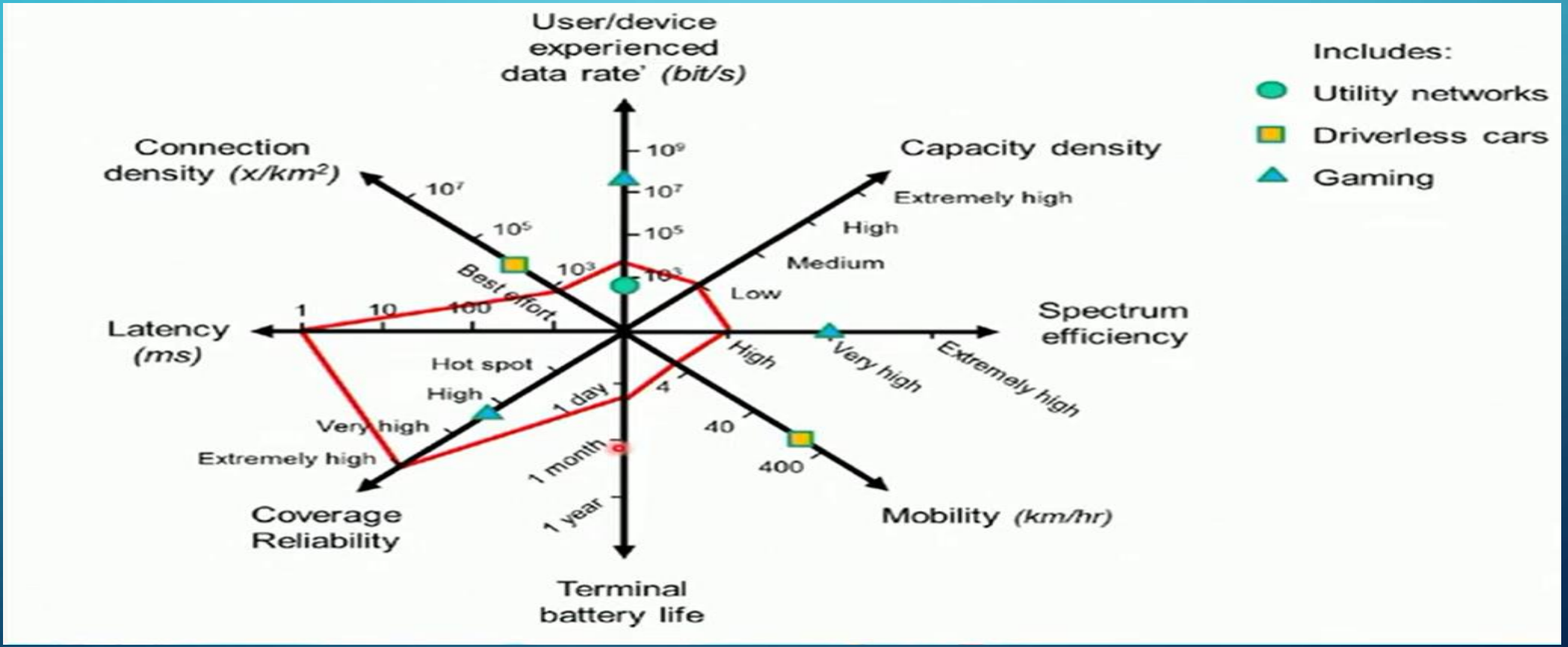
Capabilities Envisaged for Current and Emerging Multimedia Applications



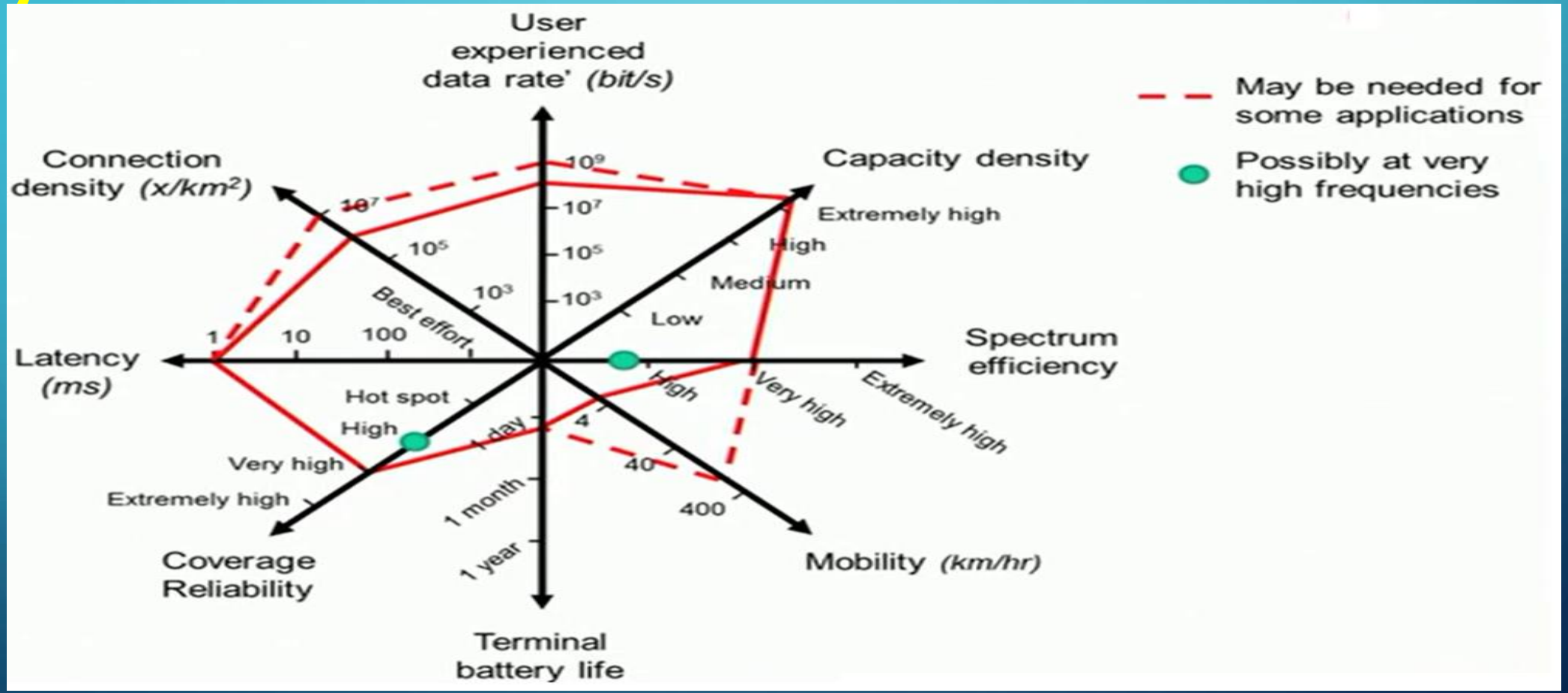
Capabilities Envisaged for Emerging Internet of Things Sensors and Actuator Applications



Capabilities Envisaged for Emerging Mission Critical and Low Latency Applications



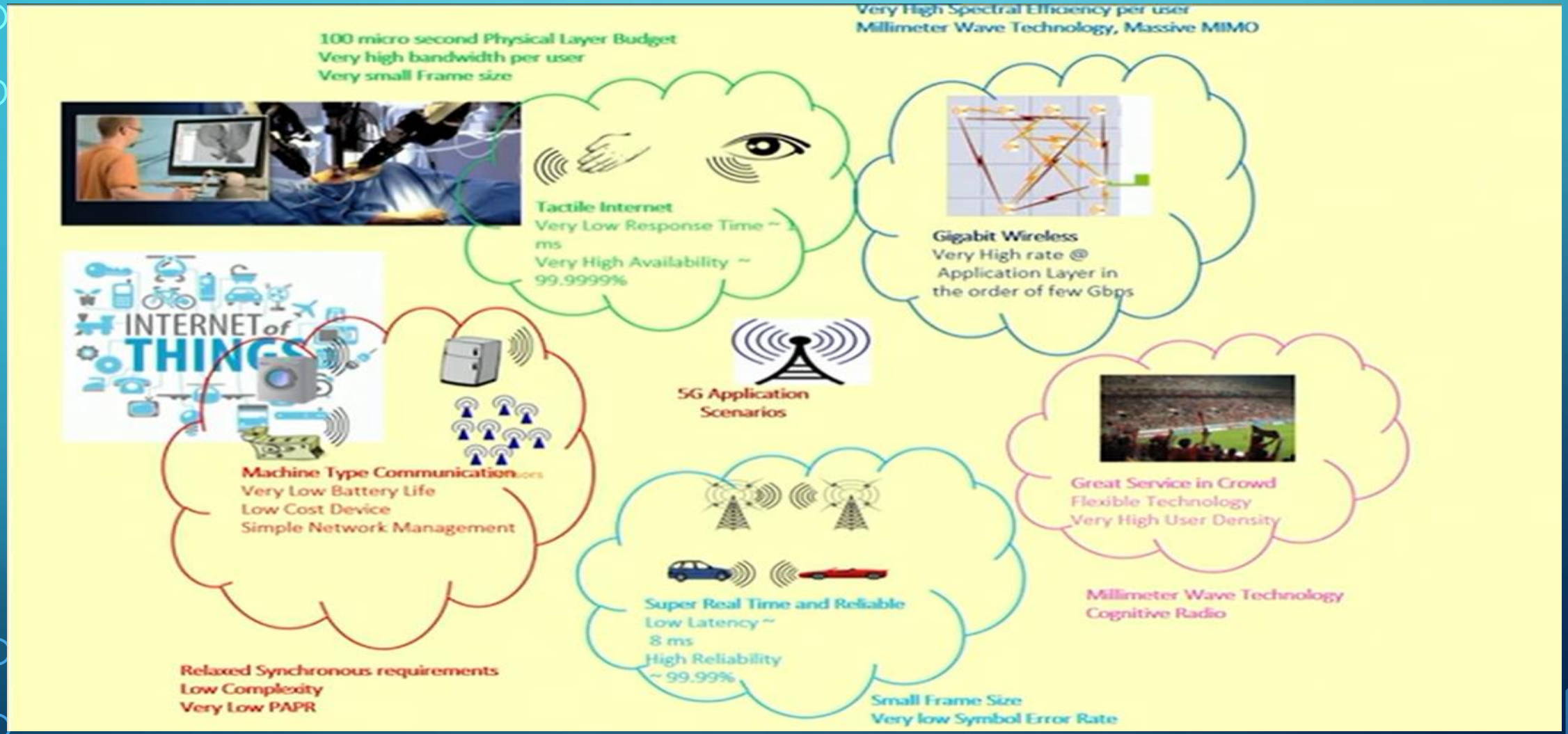
New Capabilities Envisaged for Future IMT for Beyond 2020



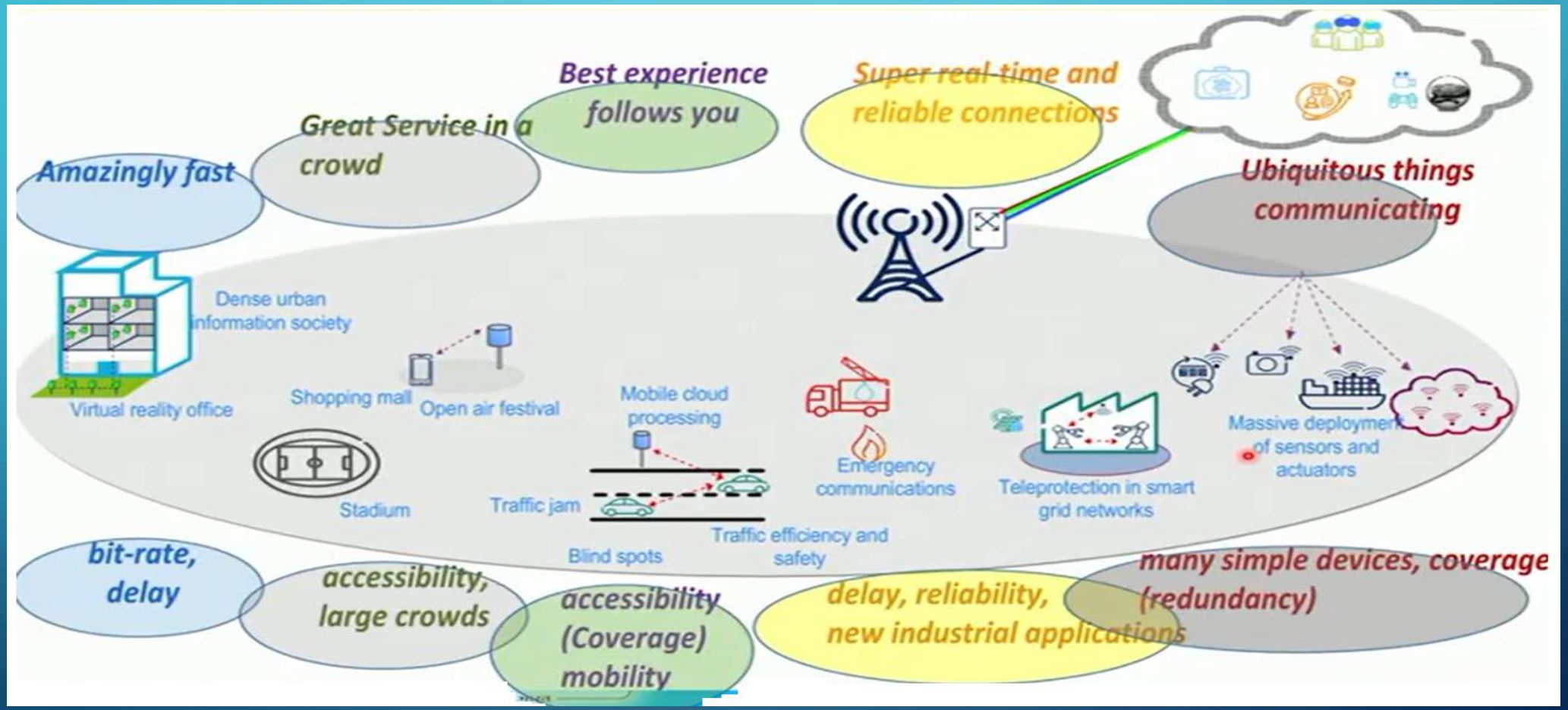
USAGE SCENARIO FOR IMT-2020 AND BEYOND

- Enhanced mobile broadband.
- Ultra-reliable and low latency communications.
- Massive machine type communications.

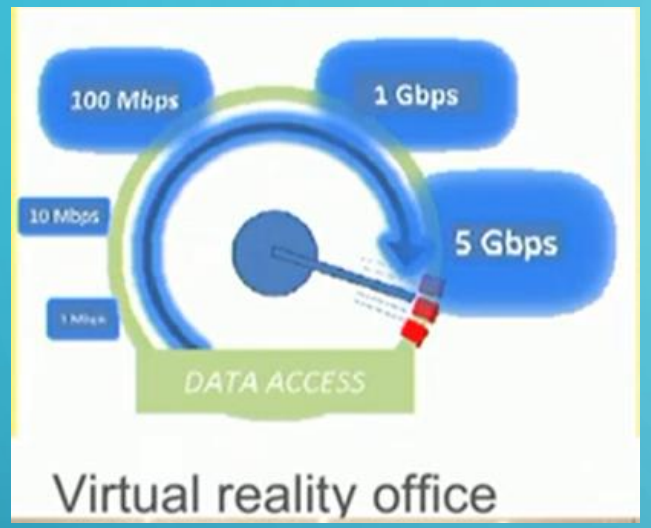
5G Scenarios



5G Scenarios



Gigabit Wireless



Dense urban information society

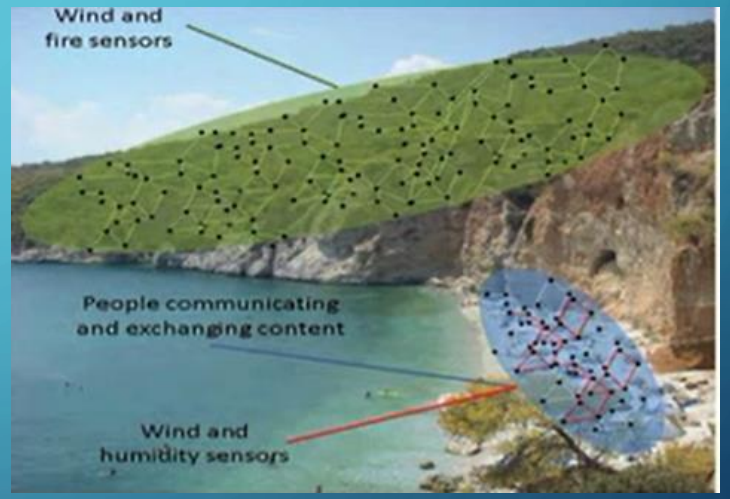
- Work and infotainment
- Amazing end user experience provided by high data rates

Great Service in Crowd

- ❖ Great user experience even in crowd
- ❖ Extreme traffic densities, dynamic in time and space
  - Shopping mall, Stadium, open air festivals, etc…

Machine Type Communication

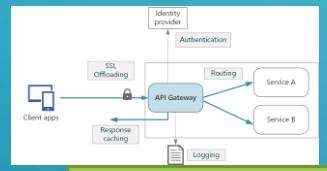
- Very large number of simple, inexpensive
- Long battery life devices, varied traffic type



Tactile Internet

- Very low response time ~1 ms and very high availability ~ 99.9999% some of the application area are

○Automation industry, Gaming, Healthcare, Tele-presence, etc…



Gateway processing

Data delay $\geq 1\ ms$

Basestation 3Km $\geq 10\ \mu s$

Data TTI frame $\geq 1\ ms$

Air channel 3Km

Terminal processing ≥0.5ms

Control panle: Idle to active ≥2.2ms

Control panle: Idle to active ≥ 5.5ms

Enhanced Mobile Broadband Through 5G

Fiber like speed
- ✓ 10X experienced throughout

Uniform experience
- ✓ 10X decreases in end-to-end latency
- ✓ 10X increase in connection density

Lower latency
- ✓ 3X spectrum efficiency
- ✓ 100X traffic capacity

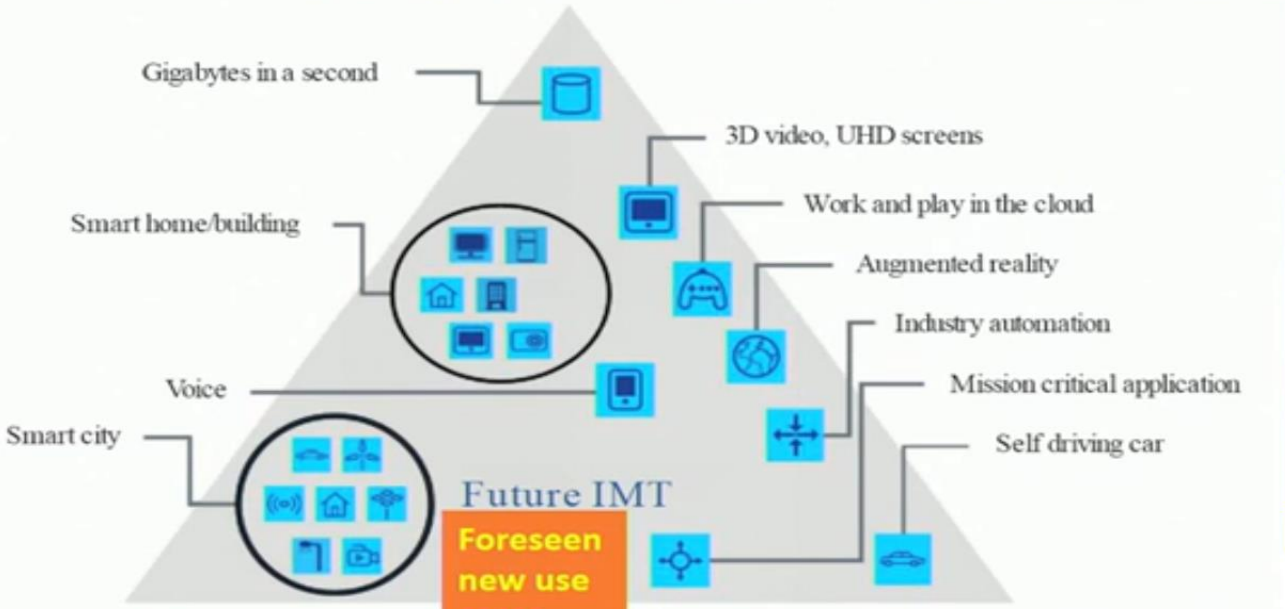
Lower cost per bit
- ✓ 100X network efficiency

5G Usage Scenarios for 2020 and Beyond

Very large number of connected devices,

Transmitting low volume non-delay-sensitive data.

Devices to be low cost, and have long battery life

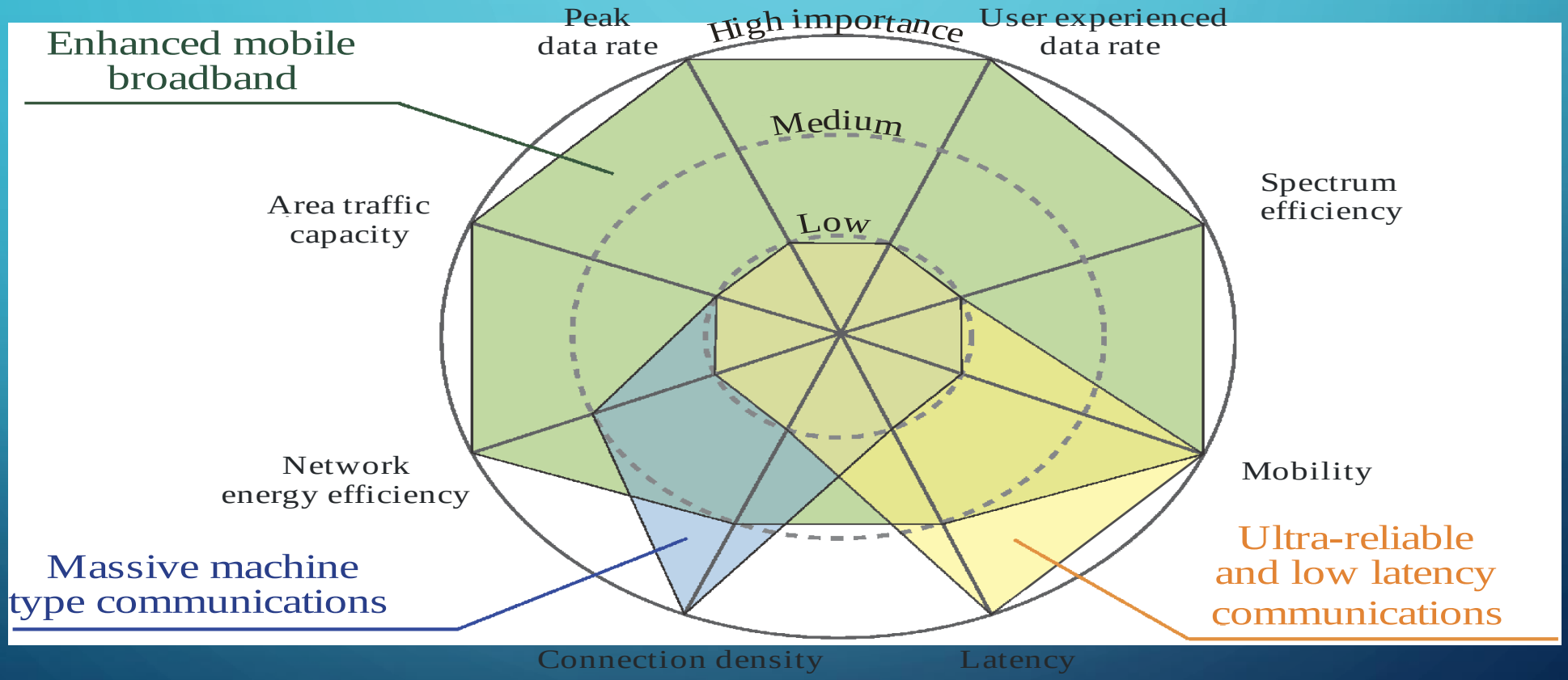


Hotspot case: -i.e. area with high user density, very high traffic capacity is needed, requirement : low mobility , high user data

Ultra-reliable and low latency communications -wireless control of industrial manufacturing
-production processes,
-remote medical surgery,
-distribution automation in a smart grid,

Key Capabilities is Important for Most Cases, But Certain Key Capabilities

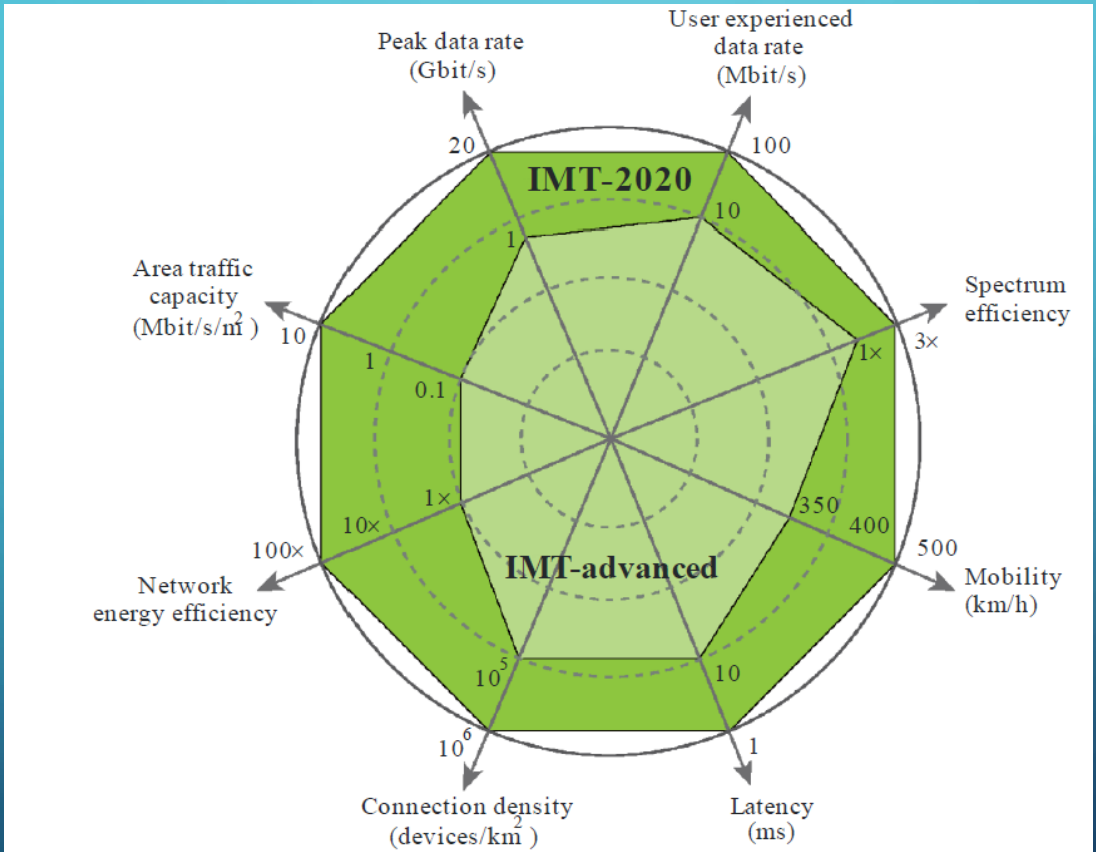
The importance of key capabilities in different usage scenarios



Enhancement of Key Capabilities From IMT-Advanced to IMT-2020

Total traffic throughput served per geographic area (in Mbit/s/m2).

per user/device (in Gbit/s).



Achievable data rate that is available ubiquitously.
ubiquitous" is related to the considered target coverage area and is not intended to relate to an entire region or country.

Average data throughput per unit of spectrum resource and per cell3 (bit/s/Hz).

Maximum speed at which a defined QoS and seamless transfer between radio nodes and/or radio access technologies (multi-layer/-RAT)

The contribution by the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

THANKS FOR YOUR ATTENTION

Email: lwaa@kecbu.uobaghdad.edu.iq

Mobile: 07723708900